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ABSTRACT

Addressing the problem of providing an appropriate mathematics education for vocational/technical students, this paper proposes the development of a technical mathematics sequence through the cooperative input of both math and technical faculty. First, introductory material discusses the liberal arts bias and lack of technical knowledge of typical technical mathematics instructors and the problems faced by technical faculty whose students are often unprepared to handle the mathematics requirements of their courses. Next, a process is suggested for developing an appropriate technical mathematics sequence, involving meetings between math and technical department faculty, the development of a list of topics to be covered in the courses, course development by the mathematics faculty, and the submission of the final course proposal for review by all involved faculty. Next, areas in which the process can break down are highlighted and methods of dealing with conflicts are presented. The next section argues that technical math courses should be taught by technical instructors, as it is probably easier for technical faculty to upgrade their math skills than for math faculty to become familiar with the appropriate applications of technical math. A list of objectives for the first course of a two-course sequence arrived at by consultations between math and technical faculty at one college, is followed by a catalog description of the course and information on design criteria and performance goals. Finally, a review of related literature is presented. (HB)

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ABSTRACT

TECHNICAL MATHEMATICS: A DILEMMA

Keith Shuert

This paper addresses the problem of how community colleges can effect an interface between the technical faculty and the math faculty with regard to appropriate mathematics education for the vocational/technical students.

A process for the development of a tech math sequence of courses is offered which involves the input of both math faculty and technical faculty on a cooperative basis. The initial thrust should come from the career faculty. After both groups mutually arrive at a list of math topics, the math faculty should formally develop the course and submit it to all the involved faculty for final approval. A number of possible resolutions are given should this cooperative venture break down.

The issue of who should teach technical mathematics is discussed. Instructors should have experience in industry and have completed math courses through calculus. The view is expressed that it is probably easier for technical faculty to upgrade their math than for the math faculty to become familiar with the appropriate applications of tech math.

A list of objectives for the first of a two course sequence in tech math is provided. The course content was arrived at by consultation between the math and the applied technology faculty at a community college.

A review of related literature is included under the headings of cooperation between mathematics and occupational faculty, technical math competencies, and technical math curriculum development.

A selected bibliography concludes the paper.

THE PROBLEM

In most community colleges, technical mathematics is offered through departments of mathematics and is taught by faculty who have degrees in mathematics and who have a liberal arts bias. They usually have little knowledge of the kinds of applications their students will meet in the various technical courses they will be taking. The math faculty tend to rely on any examples their text provides but have little actual first hand experience in the technical fields from which their students come. These math faculty certainly can prepare their students with the algebraic skills they might have to use in their technical fields; but there is no guarantee that they are giving the students the specific skills and training that the technical education faculty want their students to have.

On the other side the technical education faculty find their students poorly prepared to handle the mathematical requirements of their courses. They approach the math faculty saying that they need help. They delineate the math skills their students need for their particular discipline. The trouble is they never seem to get what they request. This situation puts the technical faculty in a bind. They can continue to beseech the math teachers to provide their students with the prerequisite math skills, with little evidence of return. They can try to take valuable classroom time out of the technical classes to teach these skills to their students. Or if their college offers apprenticeship programs, they can turn to apprenticeship math courses, which may be called an Introduction to Algebra or even Algebra, but which often are just glorified shop math courses which do not cover algebra with sufficient rigor to be applicable to a wide range of different vocational technical programs.

If technical faculty approach math faculty with their list of wants, math faculty tend to look down their list of offerings to find the course that happens to come closest to the want list. This is usually a Tech Math I and II sequence. The

problem is that most math faculty teach Tech Math I and II as though they are Beginning and Intermediate Algebra courses, mainly by default, due to their lack of experience with the technical fields they are supposed to be serving.

The problem then is how can the technical faculty and the math faculty cooperate to design an appropriate mathematics education for the vocational technical students.

A PROPOSED SOLUTION

In most cases a new Technical Mathematics sequence should be developed. In some community colleges the traditional tech math courses are no longer offered or are experiencing declining enrollments in spite of increased vocational/technical enrollments requiring math. The enrollments have shifted to apprenticeship math classes, or the standard Beginning and Intermediate Algebra courses.

The successful development of a new tech math sequence should proceed as follows:

1. It should be recognized that the development of a new tech math sequence, usually two courses, is necessary to break away from the built in, long standing biases of both math faculty and career education faculty.
2. This development should start with a series of meetings between the vocational education faculty and the math faculty. Those attending these meetings will be determined by the dynamics of any given institution. It may be department heads, discipline representatives, departmental committees of those interested, or all the vocational/technical faculty in programs requiring math with all the members of the math department.

members of the math department. Certainly, the more involvement by faculty the greater chance of a successful outcome.

3. Together these two groups of faculty should come up with a list of topics to be covered in this sequence. There should be a free flow of ideas and an open and exhaustive exhange of possible topics. The initial input and thrust should come from the vocational/technical faculty. The math faculty should accept these suggestions and expand on them, questioning precisely what math skills are needed and suggesting related skills in an attempt to pin point what is really needed, and to insure that all related and requisite skills are included. The career faculty should be as detailed in their list as possible. The math faculty should be sure all requisite skills are included but only those that are necessary to meet the requested skills.

4. The bulk of this interaction and exchange can occur at one meeting, but there should be follow up meetings to refine and polish the final list of topics.

5. The math department should then take the responsibility of formally developing the tech math sequence in accordance with the institution's curricular procedures. They have the expertise and experience to insure the sound development of these skills.

6. These courses should be submitted to all the faculty involved for final approval. This should include the vocational/technical faculty in those disciplines or programs requiring math and the math faculty. It is often at this step that the process come to a screeching halt. This sometimes occurs because all the affected faculty, especially the vocational/technical faculty, were not involved in the original deliberations. This is severely compounded if the institution is a multi-

campus institution with vocational/technical faculty and math faculty at each of several campuses. Breakdown will also occur if there has not been enough dialogue in the original meetings or if the exhange has not been sufficiently open and free of bias. The key to sucess is tolerance by each group of faculty for the views and position of the other group. The math faculty are concerned with the students' preparation for subsequent courses. The vocational/technical faculty are primarily interested in students being able to handle work applications.

However, the real threat to success and the one factor that will sabotage these efforts faster than anything is strong reluctance by either group of faculty to give up or lose student enrollments in their courses. If the math department has had enrollments in their traditional tech math sequence, they may find it difficult to give up their liberal arts bias and admit that they have not been offering tech math in the most effective way. Chances are, however, that most math departments have all the students they can handle. Their problern is most likely having too few full-time faculty and experiencing great difficulty in hiring enough part-time faculty, especially well-qualified ones, to cover all the sections they are offering. So, if the technical faculty balk at this stage, the math department most probably will discontinue its involvement.

The vocational/technical faculty are the most likely to halt the proceedings at this approval stage. Often they have been disappointed by the level of math skills of their students and have blamed the math courses for this lack of preparation. They have often chosen to fall back on their own apprenticeship math courses in lieu of the tech math courses and have enjoyed the accompanying increase in enrollments. At this juncture they will resist any attempts to supplant the apprenticeship math courses by the new tech math courses. This log jam must be dealt with head on if it occurs. Some possible solutions are:

(1) Discuss this issue from the onset and come to a mutually agreeable resolution before the development of a new technical math sequence is even started. It could be resolved by deciding which courses will require apprentice math and which will require the new, to be developed, technical math. This could be a natural result of preparing the list of required math skills for the various career courses. Those courses which require math skills that are covered in an apprentice math course would use that course. Those which better fit the technical math sequence would require the technical math course. There is obviously no place for selfish bias in these determinations, but an honest and genuine concern for the needs of the students and for the best way to meet those needs.

(2) Resolve the conflict by establishing a mutually agreeable procedure to determine who teaches the new technical math sequence. For example, the Tech Math courses could be team taught. A math instructor would cover the skills and a vocational/technical instructor would cover the applications of the skills. Or, the technical math course could be crosslisted in both the math department and the vocational technical department. The enrollment counts could then be split between both departments.

(3) Solidify the distinction between apprenticeship math and technical math by restricting apprenticehip math to apprenticehip programs, and require two-year vocational technical programs to use the technical math sequence. This solution will not likely please all the faculty, especially the apprenticeship faculty, particularly if the apprenticeship enrollments are on the wane.

(4) Decide to place the total responsibility for technical math with the vocational/technical/apprenticehip training department(s). After all,

most math faculty are not well versed on practical applications and uses of mathematical concepts and skills that they teach. They usually prefer to stress the purely mathematical aspects of their discipline. This may be a workable solution in many instances but is not the most desirable one. There is too much that is lost by the students, the faculty and the institution if this opportunity to bring about cooperation between vocational/technical faculty and math faculty is avoided. The vocational/technical faculty may not be qualified, or interested in teaching technical math. The apprenticeship courses may not meet the needs of all the career courses, shortchanging a number of students. The math faculty would miss the opportunity to expand their expertise and effectiveness as math teachers. Most of them are aware of the deficiencies in their background relative to technical math applications, and trust that strong skill development in algebra will see their students through their vocational/technical courses. Any institution certainly benefits from a healthy mutually supportive interface between vocational technical faculty and liberal arts faculty. Administrators search for ways to build these bonds and counteract the differences in ideas, values, opinions, and respect that seem to keep vocational technical faculty and liberal arts faculty apart.

WHO SHOULD TEACH TECHNICAL MATHEMATICS?

An ideal way to staff technical math courses is to have the vocational technical faculty and the math faculty get together and agree on qualifications of any faculty member wishing to teach technical math. They could form a joint committee to review the qualifications of anyone wishing to teach technical math. The department in which the technical math courses are housed would then

select from those who are declared qualified by the joint committee. Ideally, instructors should have experience in research and development in industry and have completed math courses through calculus. Certainly, instructors should be disposed to emphasizing an applied rather than a theoretical approach.

This will require preparation by both groups of faculty. Technical faculty would most likely have to update their mathematical skills before they would be prepared to teach technical math. The math faculty, on the other hand, would have to acquaint themselves with the various applications of math in the programs which the technical math courses serve. It is probably easier for the technical faculty to upgrade their math than for the math faculty to learn the appropriate applications.

A TECHNICAL MATH COURSE

Below are the objectives for the first course of a two course sequence in technical mathematics which might be called "Math For Technicians I." It is intended to be a four credit hour course. The course content was arrived at by consultation between Math faculty at one campus of a four campus community college and the Applied Technology faculty at the same campus. The recommended text for this course is Introduction to Technical Mathematics, second edition, by Allyn J. Washington, published by the Benjamin/Cummings Publishing Company, Menlo Park, California.

Catalog Description

Review of arithmetic, including fractions, decimals, percents, and ratio and proportion. Calculation with approximate numbers, and rounding off. Metrics,

measurement conversion. Operations with signed numbers and algebraic expressions. Factoring and algebraic fractions. Solving linear equations and inequalities, and literal equations. Exponents, roots, and radicals, including scientific notation. Perimeter, area, and volume of basic geometric figures. The use of calculators in the solution of technical and industrial problems will be emphasized.

Design Criteria and Performance Goals

DC I: The student will solve, without the use of a calculator, arithmetic problems in whole number, fractions, decimals, percent, and ratio and proportion.

PG I: The student will solve problems in adding, subtracting, multiplying, and dividing whole numbers.

PG II: The student will solve problems in adding, subtracting, multiplying, and dividing fractions and decimals.

PG III: The student will solve problems in percent, including finding percentage, base, or rate, given any two of the three.

PG IV: The student will solve problems in ratio and proportion, including finding the ratio of two numbers, dividing a number into a given ratio, and finding the missing number in a proportion.

DC II: The student will carry out calculations involving approximate numbers and rounding off of approximate numbers.

PG I: The student will compute with approximate numbers, using the arithmetic operations.

PG II: The student will determine the appropriate number of decimal places in an approximate calculation.

PG III: The student will round off approximate numbers to the appropriate number of decimal places.

DC III: The student will become familiar with the metric system, and will carry out conversions in both the metric and English systems, and conversions between the systems.

PG I: The student will become familar with mass and length units in the metric system.

PG II: The student will convert between units in the metric and English systems.

PG III: The student will convert units between the metric and English systems.

DC IV: The student will carry out, without the use of a calculator, the arithmetic operations with signed numbers and algebraic experessions.

PG I: The student will add, subtract, multiply, and divide signed numbers.

PG II: The student will add, subtract, multiply, and divide algebraic polynomials.

DC V: The student will factor algebraic polynomials.

PG I: The student will factor polynomials using the common factor technique.

PG II: The student will factor polynomials as the difference of two squares.

PG III: The student will factor trinomials as the product of two binomials.

PG IV: The student will factor polynomials using combinations of the above techniques.

DC VI: The student will solve linear equations and inequalities in one variable, and will solve literal equations for an indicated variable.

PG I: The student will solve linear equations that do not involve fractions.

PG II: The student will solve linear equations involving fractions.

PG III: The student will solve and graph on the number line linear inequalities involving one or more operations.

PG IV: The student will solve literal equations for any variable in terms of the other variables.

DC VII: The student will carry out simplifications and arithmetic operations with exponents, radicals, and scientific notation.

PG I: The student will carry out the arithmetic operations with algebraic expression containing positive, negative, zero, and fractional exponents.

PG II: The student will simplify radicals containing arithmetic and algebraic expressions.

PG III: The student will carry out the arithmetic operations with radicals.

PG IV: The student will convert between standard and scientific notation.

PG V: The student will multiply and divide numbers in scientific notation.

DC VIII: The student will carry out computations involving basic geometric figures.

PG I: The student will find perimeters and areas of plane geometric figures.

PG II: The student will find the surface and volume of solid geometric figures.

REVIEW OF RELATED LITERATURE

Cooperation Between Mathematics and Occupational Faculty

Very little has been written on the subject of articulation between mathematics faculty and vocational technical faculty. Davis conducted a study to determine the level of cooperation between mathematics and occupational-technical faculty in the development and delivery of occupational-technical mathematics courses at 100 randomly selected two-year colleges. Five key factors were identified as influencing the level of cooperation: (1) the quality of informal communication; (2) the process for the development and review of the content for occupational mathematics courses; (3) the departmental location of responsibility for occupational math course instruction; (4) enrollment; and (5) the age of the college. The study noted with concern four trends observed as impacting upon mathematics education. (1) Mathematics service courses are increasingly being taught by faculty outside mathematics programs. When this occurs, mathematics faculty are very likely to have no involvement in the development and delivery of those courses. (2) A substantial minority of mathematics faculty still retain the view that "career" programs are inferior to "academic" programs. (3) Limited numbers of mathematics faculty have interest in teaching mathematics service courses. (4) Limited numbers of mathematics faculty have confidence in their ability to teach mathematics service courses.

Technical Math Competencies

Anyone developing or revising technical math courses needs to determine the math skills and competencies which are required for the technical programs they service. Some work has been done to accomplish this for various occupations.

The Northeast Wisconsin Technical Institute in Green Bay, Wisconsin surveyed employer and employee expectations of and satisfaction with the mathematics competencies essential to perform in fifteen occupations. Over 1800 graduates of fifteen occupational programs in two Vocational Technical Adult Education districts in Wisconsin and their employers were surveyed by mail. A set of mathematics competencies for these occupations resulted. This led to the development of a profile matrix of mathematics competencies which lists those competencies common to all occupations and those peculiar to the fifteen specific occupations. Their report contains a master list of 600 mathematics competencies.

Samuel Self conducted a research project to develop an applied or technical mathematics curriculum which would meet the needs of vocational-technical students at the community college level. Staff members from 10 community college in Texas participated in the survey to help determine and validate job competencies for the occupational areas of diesel mechanics, auto mechanics, radio/TV repair, air conditioning, welding, machine shop, printing, drafting, and electronics. The project results include a list of the mathematical concepts requisite for entry-level competencies in each of the selected occupational areas, a set of structured, sequential technical mathematics units designed to meet the needs of vocational-technical students in the selected occupational areas, curriculum guides for each of the technical mathematics units, self-instructional learning packets for each of the technical mathematics units, and performance-

based pre-and post-tests for each of the technical mathematics units.

Edwards and Roberson surveyed 470 graduates of the six engineering technology programs at Wake Technical Institute - Architectural, Chemical, Civil Engineering, Computer, Electronic Engineering, and Industrial Engineering Technologies - and 227 of their employers to determine the science and mathematics topics most needed by engineering technicians. The survey contained 81 items under the following 17 topical areas: mechanics, fundamentals of electricity/electronics, light, sound, heat, modern physics, chemistry, biology, geology, data processing, algebra, trignometry, logarithms, geometry, analytical geometry, calculus, and statistics. The survey revealed that mathematics topics were important to all graduates, various science topics were needed for different technology areas, knowledge of computer language was important to all but architectural technicians, and science and mathematics topics were more important to graduates than to employers.

Barlow and Schill did a study to determine the kind of mathematics the electronics technical worker actually used or needed on the job. The data were gathered from 90 technical workers from 44 California electronics companies, and from 29 instructors from 45 junior colleges with electronics programs. The mathematical concepts or skills defined as essential to electronics technical workers in research and development were conversion of fractions to decimals, percent calculations of tolerance, changing percentage to decimals, conversion of metric to the American measuring system, square roots, division of signed numbers, scientific notation, estimation of arithmetic problems, multiplication and division with exponents, raising to a power with exponents, use of negative exponents, ratios, and the Pythagorean Theorem.

Newton conducted a project to identify the basic and functional mathematics skills that metal trades students needed to meet entry-level job

requirements as defined by the metal trades industry for the following occupations: combination welder apprentice, machinist helper, precision metal finisher, and sheet metal worker apprentice. He provides pretests on these skills as well as student learning projects that prepare metal trades students to read, understand, and apply the required mathematics and measuring skills.

Technical Math Curriculum Development

A number of people have been involved in the development of instructional material for technical math courses.

Queensborough Community College has a handbook designed to assist teachers of technical mathematics in developing practical curricula for their students. The underlying assumption is that technology students' needs are oriented to the concrete. The handbook describes the nature, scope, and content of curricula in Electrical Technology, Mechanical Technology, Design Drafting Technology, and Technical Physics, with particular reference to the mathematical skills which are important for the students, both in college and on the job.

Doversberger did an evaluation of the two-year engineering related technology curricula at Illinois Central College to determine appropriate course content for technical mathematics and physics, the level of theory to be taught, instructor qualifications and the appropriate department for offering these technical courses. It was found that specialized courses in mathematics and physics for technology programs should emphasize an applied rather than theoretical approach, that instructors teaching these courses should be sympathetic to technical education and have had industrial experience, and that technical mathematics and physics courses should be offered in the technology department.

Greenfield developed twenty Algebra-Packets for technical students at the community college level. Each packet contains a statement of rationale, learning objectives, performance activities, and performance tests.

Ellis and Payez developed an alternative method for teaching mathematics to occupational/technical students at Paul D. Camp Community College in Virginia. Recognizing the need for the student to see the relevance of his or her studies to his occupational goals, an effort was made to structure mathematics courses to fit specific student needs within each occupational program. Mathematical skills were broken down into groups, and the skills essential to each program were determined. Common blocks of mathematics instruction in fractions, decimals, etc., were supplemented by problems tailored to and written in the individual occupational jargon.

Melton developed a study guide to train technicians in the use of electronic instruments. The guide provides that part of the mathematics content related to algebraic and trignometric equations and their applications. The following topics are included: (1) linear equations in two unknowns; (2) trignometric equations and vectors; (3) systems of linear equations; (4) quadratic equations; (5) complex numbers - imaginary roots of quadratic equations; (6) equations containing fractions; and (7) exponential and logarithmic equations.

The Technical Education Research Center at Waco, Texas has prepared eight modules designed to strengthen mathematical and laboratory skills in the areas of units, graphing, logarithms, dimensional analysis, and basic trigonometry. The modules are titled: "Formula Interpretation"; "International System of Units"; "Logarithms and Exponents"; "Angles and Triangles"; "Vectors and Scalers"; "Dimensional Analysis"; "Reading and Drawing Graphs"; and "Precision, Accuracy and Measurement."

Flannery wrote a textbook to accompany a series of video tapes which provides information, examples, problems, and solutions relating to mathematics and its applications in technical fields. Of special interest is Chapter VI which considers the applications of mathematics to plane surveying, computer science, machine parts inspection, automotive technology, aviation, manufacture engineering processes, pharmacology, and optical technology.

The Oregon Vo-Tech Math Project provides verbal problem sets for occupational courses offered in Oregon Community Colleges. The problems were selected to provide the math skills necessary for job entry and performance in several vocational-technical occupations. An individualized format permits students to work problems in various career areas. The project also developed a booklet illustrating some of the uses of the problem sets.

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